REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 7 Period--January 1 to March 31, 1943

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The material in this report consists largely of unpublished data ~~and should be kept confidential.~~ It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

Corn Storage

Condition of Stored Corn in Illinois*

Insect Infestation

Twelve species of insects were taken in the regular sampling of all experimental corn bins in Illinois during the quarter. These insects, in order of their abundance, are: first, flat grain beetle; second, rust-red flour beetle; third, sawtooth grain beetle; fourth, foreign grain beetle. These are followed by Cynaeus angustus, which was taken only in the northern counties, grain mites, book lice, anthocorids, fungus beetles, Platydema ruficornis, cadelle and dermestids. Populations were generally low and in some bins, mostly in northern counties, many dead insects were found.

Temperature

Despite the prolonged cold weather during the past winter, bin temperatures were but slightly below those of the corresponding period in 1942. However, according to the temperature trend of Illinois bins, the minimum temperatures are not reached until mid-April and it is expected that the minimum temperatures in many bins, particularly those in northern sites, will be lower this year than in previous years.

Temperatures were mostly in the thirties and forties with some in the twenties. The lowest temperatures recorded were in bin 712 at Prophetstown, Whiteside County. The temperature at a point three feet above the floor and six feet north of center was 19° F. and at a point six feet above the floor and six feet north of center the temperature was 20° F. Both readings were taken on February 10.

No abnormally high temperatures were recorded.

Moisture

There has been a general increase in moisture content in the top 15-18 inches of corn and a general decrease in moisture content in the lower portions of corn in all Illinois bins due to the moisture coming from the corn in lower parts of the bins condensing on the cold upper portions of corn. Surface moistures in many bins rose to 20 percent or higher. Typical of these changes are the 2000 bushel steel bins at Rock Falls, Whiteside County, the data for which are shown in table 1, which also shows moisture readings of these same bins in November 1942. With the advent of warm weather it is expected that these high surface moistures will drop back to normal.

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* Reported by J. M. Wright, Bureau of Entomology and Plant Quarantine in Cooperation with Dr. M. D. Farrar, Research Entomologist, Illinois Agr. Expt. Station.

Table 1:--Vertical moisture records of 2000 bushel steel bins at Rock Falls, Whiteside County, Illinois, November 1942 and Feb. 1943

Bin No.	Vertical moistures in percentage											
	1*		2		3		5		7		9	
	1942	1943	1942	1943	1942	1943	1942	1943	1942	1943	1942	1943
206	14.63	17.96	14.82	16.31	13.59	13.64	11.73	11.43	11.25	10.60	11.12	10.47
207	15.72	19.36	15.12	18.43	14.41	14.87	12.31	11.79	11.48	11.31	11.71	11.18
208	18.56	24.97	15.25	20.32	13.22	14.68	11.38	11.43	11.31	10.60	11.48	10.82
209	14.63	17.79	15.36	16.96	13.42	13.78	12.17	11.54	11.68	10.92	11.37	10.92
211	14.30	17.96	13.26	16.49	12.96	13.53	11.25	10.92	11.31	10.47	11.68	10.66
212	12.92	16.81	13.27	14.87	12.69	12.31	10.71	10.54	11.48	9.76	10.16	9.76
Ave.	15.13	19.14	14.68	17.23	13.38	13.80	11.59	11.28	11.42	10.61	11.25	10.64

* Cell numbers of 5-foot grain probe starting from handle (surface) and reading down.

Wheat Storage

Condition of Wheat in Storage at Experimental Plots*

During January and February, the regular quarterly samples were taken from the bins at both Jamestown, North Dakota, and Hutchinson, Kansas. Insect infestation was determined from the examination of from one to five quarts of wheat from each bin.

Insect populations at Jamestown reached the lowest point since the project was begun. A total of 152 bins sampled contained no living insects, and living grain mites were found in but two of the bins.

At Hutchinson, out of a total of 144 bins sampled, 78 percent were found to be infested, 48 percent grading weevily. A large proportion of the weevily bins were being held to determine if winter temperatures could be depended upon to control insect infestation in that region. By the end of February, observations showed that, with few exceptions, temperatures in the weevily bins were comparable with those in uninfested bins. In some of the larger bins (2740- to 5000-bushel capacity) it became necessary to fumigate to prevent serious deterioration of the grain. A comparison of the infestation at the two experimental wheat storage sites is given in table 2.

Table 2:--Comparison of the insect infestation in wheat stored in steel bins at Jamestown, North Dakota, and at Hutchinson, Kansas, October, 1941, to February, 1943.

	Jamestown, N. Dakota				Hutchinson, Kansas			
	No. bins sampled	Weevily bins (%)	Infested but not weevily (%)	Total infested (%)	No. bins sampled	Weevily bins (%)	Infested but not weevily (%)	Total infested (%)
1941								
Oct.-Nov.	139	1	18	19	144	9	31	40
1942								
Jan.-Feb.	133	1	6	7	135	16	53	69
Apr.-May	139	0	4	4	135	2	59	61
July-Aug.	142	0	6	6	124	0	43	43
Oct.-Nov.	146	0	1	1	133	58	21	79
1943								
Jan.-Feb.	152	0	0	0	144	33	21	54

Six species of stored grain insects were found in the January quarterly samples at Hutchinson, as listed below:

Species	Total number in 720 qts. examined
Flat grain beetle (*Laemophloeus minutus* Oliv.)	1832
Lesser grain borer (*Rhizopertha dominica* F.)	414
Red flour beetle (*Tribolium castaneum* Host.)	116
Sawtooth grain beetle (*Oryzaephilus surinamensis* L.)	88
Long-headed flour beetle (*Latheticus oryzae* Waterh.)	60
Rice weevil (*Sitophilus oryza* L.)	58

* Reported by H. H. Walkden and R. B. Schwitzgebel, U. S. Bureau of Entomology and Plant Quarantine

Condition of wheat stored in Commodity Credit Corporation bins

A limited survey of the condition of wheat stored in Commodity Credit Corporation bins in Kansas was made early in March. In addition to intensive sampling of several bins, the condition of the grain was noted as bins were being emptied for shipment of the grain. The data for 3 typical bins are summarized in table 3. The following points are of interest:

1. The moisture content of the top 2 feet of grain in infested bins was much higher than that in uninfested bins. Also, the moisture content in the lower levels was practically the same as when the bins were filled.

2. The amount of insect damage (as determined by Kansas Grain Inspection Dept.) was much less than was expected, as estimates made in the field varied from 50 to 90 percent.

3. The damage caused by mold was confined to the top 2 feet of grain.

4. Total damage in levels below the top 2 feet did not exceed 40 percent.

5. In grain which had been turned, musty odor often occurred throughout the bin, whereas in untreated grain the musty odor was confined largely to the upper two feet.

6. These bins were filled during June, July, and August, 1942, and no inspections were made during the critical period of August through October. By that time insect populations had greatly increased, much insect dust had accumulated, and surface grain had become crusted, thus making fumigation with standard dosages virtually impossible.

7. It appears quite evident that frequent inspections (which include sampling) are required, especially during the summer and fall months, in order to discover insect infestations and apply control measures (fumigation) immediately. In all cases where wheat is loaded into bins from elevators it should be fumigated immediately. If allowed to remain without treatment for even a short time insect damage will make fumigation difficult if not impossible.

Table 3: -- Summary of results of sampling Commodity Credit Corporation bins.

Legend: RW - rice weevil; L - lesser grain borer; LH - long-headed flour beetle; RF - red flour beetle; F - flat grain beetle

BIN NO. 322 LOCATION: IUKA, KANSAS

History: (Supplied by County A.A.A.) Butler, 2000-bushel capacity. 8-24-42 - Original Grade 2 Dark Hard, 11.9% moisture, 59.4 lbs. test weight, 50 Australian Borers (Lesser grain borer). About September, 1942, sampled sample grade, 40% total damage, musty, weevily. 11-6-42 - Turned, treated with 2 gal. Coop-02 per 1000 bu. A lot of bugs; hot; 25 bushels spoiled grain.
3-4-43 - Caked east half of bin.

Location and Level	Insects No. per 1000 gm. RW	L	LH	RF	F	Moisture (%)	Damage (%) Insect	Mold	Germ.	Total	Odor	Temperature Distance from floor	°F.
Center													
9-10 ft.				12		19.5		100		100	Musty		
8-9		3		12		15.7	6	13	56	75	"	9 ft.	78
7-8		3		9		13.2	8		26	34	"		
6-7		3		9		12.1	12			12	"		
5-6				3	3	11.8	16			16	"	6 ft.	84
2.5-5.0					2	12.0	9			9	"	3 ft.	75
0-2.5	2	2		2	2	12.1	9			9	"	Floor	59
North													
9-10 ft.				24	85	13.2	10		8	18	Musty		
8-9		3	3	33	75	12.7	9		7	16	"	9 ft.	71
7-8			12		48	12.4	7		5	12	"		
6-7			9		3	12.3	3		7	10	"		
5-6		35	90	30	20	12.2	2		3	5	"	6 ft.	64
2.5-5.0	2	22		6	6	11.9	6		3	9	"	3 ft.	52
0-2.5	2	12		2	2	12.1	7		14	21	"	Floor	42

(continued)

Table 3 (continued) - BIN NO. 514 LOCATION: PRATT, KANSAS

History: Butler 2740-bushel capacity.
6-23-42 Orig. Samp. 2 dark hard; 12.1% moisture; 59.2 lbs. test weight.
10-29-42 Fumigation with Coop-02
1- 7-43 2 dark hard. Weevily. Turned.

Location and Level	Insects No. per 1000 gm. RW	L	LH	RF	F	Moisture (%)	Damage (%) Insect	Mold	Germ	Total	Odor	Temperature Distance from floor	°F.
Center												Surface	78
9-10 ft.	24	21			12	14.0	4		4	8	Weevil	12 ft.	85
												9 ft.	87
7-8					6	12.5			4	4	OK		
5-6						12.3	4			4	OK	6 ft.	94
2.5-5		4				12.6	5			5	OK	3 ft.	96
0-2.5	220	4		18	4	13.0	2		2	4	OK	Floor	59

BIN NO. 304 LOCATION: IUKA, KANSAS

History: Butler 2740-bushel capacity. Farm wheat.
6-22-42 Orig. Sample 2 hard winter; 12.6% moisture; 58.3 lbs. test weight.
12- 6-42 Fumigated. Mixture: Swan, Coop-C2, Dowfume Br 10. Turned.
3- 4-43 Sampled. Wheat in good condition. No insects.

Location and Level	Insects No. per 1000 gm. RW	L	LH	RF	F	Moisture (%)	Damage (%) Insect	Mold	Germ.	Total	Odor	Temperature Distance from floor	°F.
Center												12 ft.	44
9-10	No					12.2				0	OK	9 ft.	50
8-9						12.2				0	OK		
7-8	living					12.3				0	OK		
6-7						12.0				0	OK	6 ft.	53
5-6	insects					12.3				0	OK		
2.5-5						12.4				0	OK	3 ft.	52
0-2.5						13.0				0	OK	Floor	48

Observations on the Value of Turning Wheat in Relation to Insect Population

Three 2740-bushel bins of wheat were turned during January, in accordance with the experimental schedule. Each of these bins became infested during the summer of 1942, but no serious insect populations were present up to the time of turning. By January the grain temperature had declined to a point where the insect populations were being reduced. The results of the turning operation are given in table 4.

Table 4: -- Effect of turning on temperature and insect population in three 2749-bushel bins of wheat stored at Hutchinson, Kansas, January, 1943.

Bin No.	Before turning		After turning	
	Mean grain temperature °F.	No. of insects per 1000-gram sample	Mean grain temperature °F.	No. of insects per 1000-gram sample
7-5	43	4	39	7
7-6	45	7	43	2
8-5	45	2	43	1

From the results obtained in turning three bins, it appears that little reduction in temperature or insect population can be expected, and that under conditions of low infestation turning alone is of little value. In this connection, it is of interest to note that two untreated check bins, containing grain practically identical with that in the bins listed in table 4, also developed similar infestations during the past summer, and during the winter months a marked decrease in population has been noted. During the winter of 1941-42 the winter mortality of the insects was complete in these bins.

In contrast to the above condition, a 4000-bushel capacity bin developed an intense infestation in the lower southeast quadrant during the late fall of 1942. By January, 1943, the temperature of the grain in that portion of the bin had risen to dangerous levels. This condition offered a good opportunity to test the effectiveness of turning in cold weather as a means of arresting heating and controlling the insect infestation responsible for the rice in temperature. Accordingly, the grain was turned into bin 5-11 on February 6 by means of a grain elevator. Previous observations have shown that the wheat is exposed to air temperature for only 45 seconds as it passes from one bin to another.

Average samples taken before and after turning were graded as follows:

Before turning - Grade No. 2 hard winter; moisture, 12.7%; total damage 1.6%; odor, OK; insects: 10 flat grain beetles per 1000 grams.

After turning - Grade, sample grade, weevily; moisture, 12.9%; total damage, 3.7%; odor, sour; insects: 94 rice weevil, 32 lesser grain borer, 35 flat grain beetles per 1000 grams.

In addition, an insect traverse of the grain was made both before and after turning. The results are given in table 5. In making the insect traverse, samples from different parts of the bin were taken, by means of a grain probe, each pair of probe cells (about 12™) being examined separately for insect infestation. In this manner the insect population was determined for a vertical column at one-foot intervals from the top to the bottom of the bin in the locations indicated in table 5.

Table 5: -- Comparisen of distribution of insect populations in a 4000-bushel bin before and after turning, Hutchinson, Kansas, February, 1943.

Location and Level	Number of insects per 1000 grams										
	Before turning February 3, 1943					After turning February 8, 1943				
	RW	L	F	S	Total	RW	L	F	S	Total
Center										
11-12 ft.			15		15	120	110	25		255
10-11			35		35	60	140	135		335
9-10	5		5		10	40	50	30		120
8-9			15		15	50	40	35		125
7-8			10		10	5	5	25		35
6-7					0	15		5		20
5-6			15		15	15		5		20
4-5	5		15		20					0
3-4			15		15			10		10
2-3			25		25			20		20
1-2			20		20			15		15
0-1			15		15			15		15
Totals	10		185		195	305	345	320		970
North 2' from wall:										
11-12 ft.					0					
10-11					0					
9-10					0					
8-9					0					
7-8					0					
6-7					0					
5-6					0					
4-5					0					
3-4			10		10					
2-3					0					
1-2	5				5					
0-1	5				5					
Totals	10		10		20					
North 4' from wall:										
11-12 ft.					0	20		5		25
10-11					0	160		10		170
9-10					0	20	20	10		50
8-9					0	60	75	90		225
7-8					0	70	55	85		210
6-7					0	10		10		20
5-6					0	20		5		25
4-5					0	25	5	5		35
3-4					0	5	5	5		15
2-3					0	5		5		10
1-2					0			15		15
0-1					0			10		10
Totals					0	395	160	255		810

(continued)

Table 5 (continued)

Location and Level	Number of insects per 1000 grams										
	Before turning					After turning					
	RW	L	F	S	Total	RW	L	F	S	Total
East										
4' from wall										
11-12 ft.					0	90	10	25		125
10-11			5		5	60	15	15		90
9-10	5		5		10	75	25	25		125
8-9					0	30	15			45
7-8	5		10		15	120	35	25		180
6-7	20		15		35	30	15	40		85
5-6	15		10		25	30				30
4-5				5	5	5		15		20
3-4		5	20		25		5	5		10
2-3		30	10		40	20		5		25
1-2	130	35	70	15	250	10	5	10		25
0-1	90	35	80		205		5	5		10
Totals	265	105	225	20	615	470	150	170		770
South										
2' from wall										
11-12 ft.		5			5					
10-11					0					
9-10					0					
8-9					0					
7-8					0					
6-7					0					
5-6					0					
4-5	135	25	20		180					
3-4	45	5	20		70					
2-3	215	25	80		320					
1-2	240	40			280					
0-1	25				25					
Totals	660	100	120		880					
South										
4' from wall										
11-12 ft.			10		10	10	15	15		40
10-11			25		25	50		5		55
9-10			5		5	50	10	10		70
8-9					0	30	20	35		85
7-8	5		20		25	35	10	45		90
6-7			10		10	20	5	10		35
5-6			15		15	5		5		10
4-5					0		5			5
3-4			20		20		10			10
2-3			20		20	10		5		15
1-2			60		60			10		10
0-1			75		75					0
Totals	5		260		265	210	75	140		425

(continued)

Table 5 (continued)

Location and level	Number of insects per 1000 grams										
	Before turning					After turning					
	RW	L	F	S	Total	RW	L	F	S	Total
West 4' from wall:										
11-12 ft.					0	20		15		35
10-11			20		20	75				75
9-10					0	60	5	5		70
8-9			10		10	10	60	10		80
7-8			15		15	55	90	20		165
6-7					0	75	70	20		165
5-6			5		5	25		15		40
4-5			1		1	15		10		25
3-4			10		10	20		25		45
2-3			5		5	5	5	5		15
1-2					0			30		30
0-1					0	20	10	5		35
Totals			66		66	380	240	160		780

Legend: RW = Rice weevil F = Flat grain beetle
L = Lesser grain borer S = Sawtooth grain beetle

In table 5 it may be noted that:

1. Before turning, the insect population was largely concentrated in the lower south and east portions of the grain, but with the flat grain beetle more generally distributed than either the rice weevil or the lesser grain borer. The north side was relatively free from insects.

2. Samples taken two days after the grain was turned showed that the insect population had been thoroughly dispersed throughout the entire grain mass but with the largest numbers in the upper half of the bin.

Before turning, the intense insect infestation was confined to about 200 bushels of grain, with probably less than 10 bushels in bad condition. Turning had the effect of dispersing the sour grain throughout the entire 4000 bushels, causing it to be graded sample grade because of odor.

After turning, the average temperature in the top half of the bin was 68° F., which was warm enough to permit increase in insect population. Temperature readings, and samples were taken at intervals after the bin was turned, and these data are given in table 6.

Table 6: -- Insect population and temperature changes in turned wheat heavily infested with insects, Hutchinson, Kansas, February-March, 1943. Bin 5-11.

Date of sampling 1943	Number of insects/1000 gms. Ave. sample from top half of bin						Mean grain temperature in top half °F.	Condition of surface of grain
	RW	F	L	LH	RF	Total		
Feb. 6	94	35	32			161	68	Many insects
Feb. 13	105	44	62			211		" "
Feb. 23	59	56	86	3	6	210	89	
Mar. 3	60	22	66		2	150		Crusting- moisture 17%
Mar. 9	44	24	72			140	94	Top 8" crusted

Four weeks after turning, a crust had begun to form in the surface grain as a result of accumulation of moisture in the surface foot. The moisture content of the surface grain immediately after turning was 12.7%. On March 3, samples were taken at intervals in the top 24 inches of grain, to determine the amount and location of moisture accumulation during the four weeks since the bin was turned. These were as listed below:

Location of sample	Moisture content
Surface	14.2
2" below surface	16.5
4" " "	16.9
6" " "	15.4
8" " "	13.9
12" " "	13.5
24" " "	12.8

The moisture content 24 inches below the surface was practically the same as the average for the entire bin. High moisture content of the top foot of grain together with high temperatures therein caused mold development, and by March 9 the upper 8 inches was crusted and moldy, and would support the weight of men taking samples.

In order to prevent further deterioration of the grain, the top foot was stirred, breaking up the crust, and the bin fumigated on March 9 with a dosage of 3 gallons of carbon bisulphide per 1000 bushels. Samples taken before and after fumigation showed that more than 90% of the native population had been killed, and four days after fumigation the average temperature of the bin had fallen three degrees. There were, however, two small pockets of insects which escaped the fumigation. The reason for this is obscure, but it is thought that the high moisture level of the grain at these points may have been responsible. It was decided to give the bin a second fumigation, and as a result it now appears that the native population has been completely wiped out. An insect traverse made on March 20, seven days after the second fumigation, failed to reveal a single living insect, and temperature observation on that date showed that the average temperature of the grain had dropped 14 degrees. The data pertaining to the above operations are presented in table 7.

Table 7: -- Effect of fumigation with carbon bisulphide on the insect population in bin 5-11, Hutchinson, Kansas, March, 1943.

Location and level	Number of insects per 1000 grams of wheat										After 2nd fumigation Total
	Before first fumigation March 9, 1943					After first fumigation March 13, 1943					
	RW	L	F	RF	Total	RW	L	F	RF	Total	
Center											
10-13 ft.	36	140	39		215					0	0
7-10	33	90	18	3	144					0	0
3½-7	12	12	18		42					0	0
0-3½	3		6		9					0	0
Totals	84	242	81	3	410	0	0	0	0	0	0
North											
10-13 ft.	75	60	51		186					0	0
7-10	90	54	30		174	9	27	18		54	0
3½-7	24	18	6		48					0	0
0-3½	3		9		12					0	0
Totals	192	132	96	0	420	9	27	18	0	54	0
East											
10-13 ft.	78	72	12		162					0	0
7-10		(Not sampled)									
3½-7	3		6		9					0	0
0-3½	48	12	15		75					0	0
Totals	129	84	33	0	246	0	0	0	0	0	0
South											
10-13 ft.	24	75	66	3	168					0	0
7-10	90	60	24	3	177	30	42	6		78	0
3½-7					0					0	0
0-3½	3		3		6					0	0
Totals	117	135	93	6	351	30	42	6	0	78	0
West											
10-13 ft.	12	18	48		78					0	0
7-10	6	24			30					0	0
3½-7	15	18	12		45					0	0
0-3½	48	48	12		108					0	0
Totals	81	108	72		261	0	0	0	0	0	0
Grand Totals	603	701	375	9	1688	39	69	24	0	132	
Ave. No. insects per 1000 g.	32	37	20	0.5	89	2	3	1	0	6	

Temperatures (degrees F.)

Date	Maximum	Minimum	Mean*	Remarks
Feb. 6	86	40	68	
Feb. 23	103	44	91	
Mar. 9	107	44	98	Immediately before the first fumigation
Mar. 13	103	42	95	Four days after first fumigation
Mar. 17	95	44	90	Four days after second fumigation
Mar. 20	92	44	84	Seven days after second fumigation

* Average of 15 readings in different parts of the bin.

Effect of Turning and Screening Wheat on Insect Populations in Wheat Stored in Steel Bins

Turning and cleaning grain is an established grain storage practice in line and terminal elevators where large quantities of grain are in storage. In order to determine the efficiency of this practice as applied to small lots of wheat stored in steel bins of from 1000- bushels to 4000-bushels capacity, a series of bins were assigned for this purpose at both Jamestown and Hutchinson. Due to consistently low insect infestation at the Jamestown site, no information has been obtained to date. At Hutchinson, however, insect populations have been much more intense, and the value of turning and cleaning grain has been tested as a means of controlling insect infestations. The results of turning and screening six bins of wheat are given in table 8. It may be noted that (1) the apparent reduction in insect population varied from 55 to 92 percent, and that the amount of dockage removed varied from 50 to 85 percent, the average being 78 and 68, respectively; (2) screening removed a large proportion of the bran bugs, but internal feeders (lesser grain borer and rice weevil) were retained.

Records on the turning and screening operations showed that the cost varied from one to five cents per bushel. In general, it would appear that turning and screening wheat as a means of insect control is of doubtful value.

Table 8: -- Effect of turning and screening of wheat on insect populations in grain stored in steel bins, Hutchinson, Kansas, January, 1943.

Bin No.	Capacity (bu.)	Before turning and screening: No. insects per 1000 grams L	RW	RF	F	S	LH	Total	Into bin No.	After turning and screening: No. insects per 1000 grams L	RW	RF	F	S	LH	Total	Insects removed (%)	Dockage removed (%)
11-12	1000	1			8			9	12-11	4						4	55	50
12-11	"	5		25	23		32	85	12-12	16		6	1		2	25	70	65
1-15	"				12	5		17	1-14					2		2	88	67
1-14	"	24			38		3	65	2-15	2	1		1	1		5	92	69
7-11	2740	1			7	3		11	8-10					4		4	64	72
5-9	"	3	1		3			7	6-11	1				1		2	71	85
Totals		34	1	25	91	8	35	194		23	1	6	2	8	2	42	78	68

Legend: L - Lesser grain borer
RW - Rice weevil
F - Flat grain beetle
RF - Red flour beetle
S - Sawtooth grain beetle
LH - Long-headed flour beetle

Role of Insect Infestation in Relation to Surface Caking and Molding of Wheat Stored in Steel and Wood Bins

Observations made at the Hutchinson storage site and at other bin sites in Kansas show that the surface grain in insect-infested bins is likely to become caked and moldy during the fall and winter months.

At Hutchinson none of the infested bins which were fumigated effectively before cold weather (Nov. 1) have caked. Bins which were badly infested in the fall and allowed to go into the winter without treatment became crusted early in November. In undisturbed bins the crusting occurred in the southwest quadrant, directly over the center of infestation. In one instance where the insects were scattered throughout the grain mass as a result of turning, the entire surface became crusted within five weeks after the grain was moved.

When insect populations have increased to the point where heating of the grain begins, and, as the surface grain cools with the advent of cooler fall air temperatures, a steep temperature gradient is established in the upper layer of grain. The surface grain temperature may be as low as 40° F., while in the center of insect infestation---one to five feet below the surface---the temperature is frequently 100° F. or higher. This condition causes a shift in the moisture content of the grain, and the water vapor from the warm grain rises and is condensed in the cool surface grain. The amount of moisture shift and concurrent accumulation of moisture in the surface grain varies with the size and intensity of the insect infestation, and the length of time that the condition is permitted to continue undisturbed. The grain in which the insects are active usually has a lower moisture content than adjacent uninfested grain, but the surface grain becomes muchwetter. Cases have been observed where the average moisture content of the grain mass was 11 percent but under conditions of heavy infestation, the moisture content of the surface grain increased to 20 percent or more in less than four months.

As the moisture content of surface grain increases, various molds develop, forming a crust which under extreme conditions may attain a depth of 12 inches, with surface grain germinating. Under such conditions effective fumigation is difficult. However, at the Hutchinson site, both the caked and high moisture grain were removed, and the fumigant was applied to the area from which the bad grain had been removed. It was found that increased dosages, up to two or three times normal, were required to obtain good kills.

Effect of Fumigation on the Viability of Wheat Stored in Tight Steel Bins

The Effect of Methyl Bromide

Mention has been made in previous reports of the effect on viability of fumigants containing methyl bromide. Observations have been made on two series of bins, one to test the effect of a single fumigation, and the other to observe the effect of repeated fumigations at intervals of one month. These bins all received a standard dosage, of two gallons per 1000 bushels, of a fumigant mixture containing 67.5 percent ethylene dichloride, 22.5 percent carbon tetrachloride, and 10 percent methyl bromide. The results are tabulated in tables 9 and 10. From the data given in table 9, it appears that one fumigation reduced the germination from 27 to 59 percent with an average reduction of 48.7 percent, while in four unfumigated bins the reduction in germination ranged from one to 13 percent, with an average reduction of 7.7 percent. These germination tests were all made by the Bureau of Plant Industry and were standard soil tests.

From table 10 it may be seen that the average reduction per fumigation was 10.5 percent.

As a result of the above tests, there appears to be but little doubt that fumigants containing 10 percent methyl bromide applied at the rate of two gallons per 1000 bushels of grain have a deleterious effect on the viability of wheat stored in tight steel bins such as those at the Hutchinson site. Dr. C. H. Richardson, Iowa Agricultural Experiment Station, in cooperation with the Bureau, is conducting laboratory tests with various fumigants to determine their effect on viability of both corn and wheat. These tests are still in progress, but from initial results with ethylene dichloride-carbon tetrachloride mixtures it appears that these compounds cause no reduction in germination, even in concentrations much greater than would be encountered with standard dosages. Therefore, the addition of methyl bromide appears to cause the reduction in germination. A detailed report of Dr. Richardson's results will be given in a later report.

Observation at Hutchinson in one tightly sealed bin of 5000-bushel capacity which was fumigated with a 3-to-1 mixture of ethylene dichloride and carbon tetrachloride has shown no reduction in germination three months after fumigation. The record is as follows:

Bin 5-12, fumigated No. 7, 1942; dosage 3 gals. per 1000 bushels.

Germination before fumigation,	Nov. 7, 1942	82	percent
" after	" , Nov. 10, 1942	84	"
" "	" , Feb. 17, 1943	85	"

Table 9: -- Effect on viability of one fumigation with mixture containing 10 percent methyl bromide in wheat stored in steel bins, Hutchinson, Kansas, 1941-1942.

Bin No.	Capacity (bu.)	Date sampled	Germination (%)	Date fumigated	Date sampled	Germ. (%)	Date sampled	Germ. (%)	Total change
1-6	1000	6/26/42	76	8/31/42	9/17/42	45			-31
1-7	"	"	75	"	"	39			-36
1-8	"	"	77	"	"	49			-28
1-9	"	"	77	"	"	44			-33
2-5	"	6/22/41	70	11/20/41	3/31/42	53	6/26/42	43	-27
2-7	"	6/23/41	84	"	6/26/42	63	9/17/42	36	-48
2-8	"	8/17/42	68	8/19/42	8/29/42	17	9/17/42	17	-51
2-9	"	"	67	"	"	12			-55
3-8	"	6/29/42	74	"	"	15			-59
4-9	"	8/17/42	54	"	"	9			-45
11-4	2740	6/26/42	67	"	"	12			-55
9-11	"	6/17/42	80	8/3/42	8/31/42	46			-34
Mean			72.4			33.7		32.1	-48.7
				Unfumigated checks					
3-10	1000	6/21/41	85		4/2/42	81	6/29/42	74	-11
3-11	"	"	86		"	83	"	73	-13
5-1	2740	6/24/41	86		4/6/42	84	6/19/42	80	- 6
6-2	"	"	81		"	89	"	80	- 1
Mean			84.5					76.8	- 7.7

Table 10: -- Effect on viability of successive fumigations with mixture containing 10 percent methyl bromide in wheat stored in steel bins, Hutchinson, Kansas.
A = rag doll test B = soil test

Bin No.	Capacity (bu.)	Type of test	% Germ. before fumigation	% Germ. after 1st treatment	% Germ. after 2nd treatment	% Germ. after 3rd treatment	% Germ. after 4th treatment	Change Total	Change Ave.
1-2	1000	A	85	81	76	65		-20	- 7
2-16	"	A	90	61	84			- 6	- 3
8-12	"	A	68	29	--	27		-41	-14
8-12	"	B	45	--	--	2		-43	-14
11-9	2740	A	79	29	59	37		-42	-14
11-9	"	B	58	--	--	6		-52	-17
11-11	"	A	70	45	72	50		-20	- 7
11-11	"	B	52	--	--	26		-26	- 9
12-9	"	A	55	38	--	28	22	-33	- 8
12-9	"	B	48	--	--	--	1	-47	-12
Mean			65.1					-33	-10.5

Effect of Chloropicrin on Germination

Five bins were fumigated with varying dosages of a mixture of chloropicrin and carbon tetrachloride. The germination before and after fumigation, together with the dosage, are given in table 11. While these tests included only a small number of bins, it appears that the heavier dosages of chloropicrin may have a deleterious effect on the viability of the grain. It should be borne in mind that these tests were conducted in cold grain (40°F.) in all of the 1000-bushel bins. The average temperature of the 2740-bushel bin (12-4) was 65°F. Under summer conditions the effect might be more marked. In general, there appears to be a tendency toward greater reduction in germination in grain which had lower initial viability.

Table 11: -- Effect on viability of one fumigation with mixtures of chloropicrin and carbon tetrachloride in wheat stored in steel bins, Hutchinson, Kansas

Bin No.	Capacity (bu.)	Mixture: Chloropicrin (lbs.)	Mixture: CCl_4 gals.	Dosage per 1000 bu. (gals.)	Before fumigation: Date sampled	Before fumigation: Germ. (%)	Date treated	After fumigation: Date sampled	After fumigation: Germ. (%)	Germination loss (%)
12-4	2740	2	2	2	1/15/43	56	1/23/43	1/30/43	33	-23
1-16	1000	2	1	1	2/ 6/43	77	2/ 6/43	2/13/43	76	- 1
2-16	"	2	1	2	"	80	"	"	75	- 5
8-12	"	1.5	1	2	"	86	"	"	85	- 1
9-13	"	1	1	3	"	75	"	"	44	-31

Experimental Fumigation of Wheat

During the quarter just past, a considerable amount of experimental fumigation, chiefly in cold grain, has been in progress.

Tests were made with various mixtures of carbon bisulphide and carbon tetrachloride; with chloropicrin in carbon tetrachloride; and with a fumigant sold as Coop-02, the analysis of which is not known. The tests with the latter material were made at the request of the Reno County AAA Committee, even though tests with materials of unknown composition are contrary to usual policy. This material has been used extensively in grain fumigation in Kansas during the past season, and the results were reported variously; hence the tests were made at Hutchinson in order to have reliable information at hand.

The effectiveness of the various mixtures was determined by means of check probes containing live insects placed in the grain. The results of the various fumigations are given in table 12. In these tests, the various mixtures of carbon disulphide show up favorably, dosages as low as 2 gallons per 1000 bushels of the 1:4 mixture giving good kills.

With chloropicrin, the results were not so good, and at the higher dosages some bad effect on germination was observed, as discussed previously.

The material sold as Coop-02 gave very poor results at the one-gallon dosage recommended by the jobber.

Table 12: -- Results of experimental fumigation of wheat stored in steel bins, Hutchinson, Kans. January-February, 1943.

Fumigants: A = Ethylene dichloride-carbon tetrachloride
B = Carbon disulphide-carbon tetrachloride
C = Carbon disulphide (alone)
D = Chloropicrin (2 lbs.)-CCl_4 (2 gals.)
E = " (2 ")- " (1 ")
F = " (1.2 ")- " (1 ")
G = " (1 ")- " (1 ")

Bin No.	Capacity (bu.)	Date	Mean* grain temp. (°F.)	Fumigant	Dosage per 1000 bu. (gals.)	Mortality in check probes (%)	Mortality control (%)
6-3	2740	1/ 6/43	49	A (3:1)	4	93	30
7-10	"	2/19/43	39	B (1:4)	3	100	20
8-9	"	"	39	B (1:4)	4	100	20
4-12	1000	1/23/43	40	B (1:4)	6	100	9
1-10	"	2/ 1/43	40	B (1:4)	5	99	15
3-4	"	2/19/43	40	B (1:4)	4	100	20
2-11	"	"	40	B (1:4)	3	91	20
2-10	"	"	40	B (1:4)	2	95	20
1-9	"	2/ 1/43	40	B (1:3)	4	99	15
1-8	"	"	40	B (1:2)	3	99	15
3-13	"	1/23/43	38	B (1:1)	4	100	9
1-7	"	2/ 1/43	40	B (1:1)	2	100	15
2-13	"	1/23/43	38	C	3	100	9
1-6	"	2/ 1/43	45	C	2	100	15
3-5	"	2/19/43	40	C	1	83	20
12-4	2740	1/23/43	65	D	2	87	30
2-16	1000	2/ 6/43	40	E	2	65	14
1-16	"	"	40	E	1	55	14
8-12	"	"	40	F	2	92	14
9-13	"	"	40	G	3	100	14
11-10	2740	1/ 6/43	47	Coop-02	1	53	30
11-11	"	"	47	Coop-02	1	42	30
12-10	"	"	47	Coop-02	1	43	30

* Determined from 15 to 25 temperature readings in various parts of the bin.

Retention of Fumigants in Tight Steel Bins

In previous reports, the retention of various fumigants in grain has been discussed. During the past quarter, further observations have been made on the retention of carbon bisulphide and also the 3:1 mixture of ethylene dichloride and carbon tetrachloride.

One 2740-bushel bin of wheat (No. 8-8) at Hutchinson was fumigated with a dosage of 3 gallons of carbon bisulphide per 1000 bushels on February 20, 1943. On February 22, the grain was transferred to bin 7-9 and check capsules of insects were put in the bin on February 23. These were removed on February 26 and the mortality recorded at the levels listed below:

Distance above floor (Ft.)	Mortality (%)
9	95
6	96
3	97
Floor	97

Mortality in control (check) 1%.

From the above data it appears that even though the grain is turned a short time after fumigation, enough of the fumigant is retained to produce lethal concentrations for more than three days.

One 5000-bushel bin of wheat was fumigated November 7, 1942, with a dosage of 3 gallons per 1000 bushels, of 3:1 mixture of ethylene dichloride and carbon tetrachloride. This bin is constructed of steel plates bolted together, the joints being sealed with rubber gaskets, and is nearly gas tight. Originally it was built to hold gasoline. Check probes were put in this bin on February 18, 1943, and removed on March 10. The mortality in the check capsules was as follows:

Distance above floor (Ft.)	Mortality (%)
12	100
9	100
6	90
3	100
Floor	100

It would appear that killing concentrations were retained for nearly four months.

Sampling Methods

In an effort to develop a satisfactory sampling method for practical field use, different ways of sampling grain stored in steel bins have been tried. During the fall and winter months comparisons were made between samples drawn from the north and south quadrants of the bin and an average sample taken from 10 different places in the bin. The latter method is the one which has been used at the Hutchinson and Jamestown sites to determine changes in commercial grade, insect infestation, etc. The data are given in table 13. From the table it will be seen that in only six cases, out of a total of 35 bins sampled, did the infestation in the average sample exceed that in the south sample. The samples taken from the north quadrants of the bins were generally less infested than were the average samples. On the average, the infestation in the south samples was more than four times greater than in the average samples. Based on the results obtained in this series of bins, sampling in the south quadrant of the bin is most likely to reveal heavy infestations, late in the fall.

Table 13: -- Comparison of sampling methods in wheat stored in steel bins, Hutchinson, Kansas.

Legend: L = Lesser grain borer S = Sawtooth grain beetle RW = Rice weevil
F = Flat grain beetle RF = Red flour beetle LH = Long-headed flour beetle

Bin No.	Date sampled	Capacity (bu.)	Number of insects per 1000 grams																					
			North samples							South samples							Average samples							
			L	RW	F	RF	S	LH	Total	L	RW	F	RF	S	LH	Total	L	RW	F	RF	S	LH	Total
5-4	11/17/42	2740	4			1			5	46	1	6	1			54	12		11	1			24
6-1	"	"			8		2		10	23		25	10	4	1	63	7		12	6	3		28
5-4	12/18/42	"			2				2	15						15	1						1
6-1	"	"				1			1	4			14		1	19	6			3	1		10
6-4	"	"							0	2			1			3	1			1			2
9-7	"	"					1		1	5						5	1						1
11-3	"	"		1					1	67		9	22	3	178	279	4		1	1		4	10
11-4	"	"							0	2						2							0
11-5	"	"		1					1	13	5	1	6		63	88	1	2	1	2		2	8
5-1	"	"		2	1				3	4	1	1				6	1						1
5-5	"	"			5	1			6			13		1		14		3	8	1			12
5-6	"	"	1	1	7				9	26	49	96	4			175	5	5	2	1			13
6-2	"	"							0	2		7				9			2				2
6-3	"	"	4	1	3				8	3	3	6				12	6		11				17*
6-7	"	"			1				1	14	52	11	1			78	6	18	8	3			35
6-8	"	"		1	1		1		3	1		7				8	1		10				11*
9-4	"	"	1		7				8	8		1		9		18	9			2	2		13
9-5	"	"		1	3				4	2	1	6				9	1		20				21*
9-6	"	"	3		18				21	9	35	21				65	6		7				13
10-4	"	"							0	7		18				25			4	1			5

* Cases in which the infestation in the average sample exceeded that in the south sample.

(continued)

Table 13 (continued).

Bin No.	Date sampled	Capacity (bu.)	Number of insects per 1000 grams: North samples L	RW	F	RF	S	LH	Total	South samples L	RW	F	RF	S	LH	Total	Average sample L	RW	F	RF	S	LH	Total
10-6	12/18/42	2740			10				10	3	2	3				8	1		8				9*
11-2	"	"	1		3				4	1		2				3	1		14				15*
12-1	"	"			2				2			9				9			10				10*
12-2	"	"			9				9	2	67	18				87	1	10	14		1		26
2-13	12/22/42	1000			5				5	2		5				7			6				6
3-13	"	"	1		7				8	1		9				10			8				8
4-12	"	"			7				7			6				6			2				2
11-6	"	2740	3					1	4	3		1				4			1				1
11-7	"	"	1		7				8	1	3	5				9	1	2	2				5
6-8	1/4/43	"	Not sampled							1		10				11			1				1
6-13	"	4000	Not sampled									7				7	1		5				6
10-5	"	2740	"		"							37				37	1		4				5
11-6	"	"	"		"					6		7				13	1		2				3
11-7	"	"	"		"					5	5	9				19	1	2	2				5
7-4	1/6/43	"	"		"					154		93		185		432	13		6		8		27
Totals			19	8	106	3	4	1	141	432	224	449	244	17	243	1609	89	42	182	30	7	6	356
Average			0.7	0.3	3.7	0.1	0.1	0.1	2.9	12.4	6.4	12.8	7.0	0.5	6.9	45.9	2.6	1.2	5.2	0.9	0.2	0.2	10.2

* Cases in which the infestation in the average sample exceeded that in the south sample.

The Effect of Temperature and Moisture Content of Grain on the Survival, Reproduction and Development of Certain Grain Infesting Insects in Clean Wheat*

The experimental work described in this report is a continuation of experimental work that has been in progress for the past two years, in which an effort is made to evaluate the factors of temperature and grain moisture as affecting the survival, reproduction and development of six common species of stored grain insects. The tests herewith reported on deal with observations on the ability of these insects to survive and reproduce in 12, 13, and 14% moisture wheats at constant temperatures of 65, 70, and 75° F.

The species included in the tests were the granary weevil, the rice weevil, the lesser grain borer, the confused flour beetle, the rust red flour beetle, and the sawtoothed grain beetle. In a previous series of tests conducted at a constant temperature of 70° F. with 9, 10, and 11% moisture wheat, it was found that none of the species reproduced in clean wheat of 9% moisture content. The granary weevil reproduced although sparingly in 10% and 11% wheat and the rice weevil in 11% wheat. None of the other four species showed signs of reproducing at this temperature in wheat of the above mentioned moisture levels.

In the experimental work described herewith 100 adults of each species selected at random were placed in separate cultures of 12, 13, and 14% moisture wheats, and one series maintained at a constant temperature of 65° F., another at 70° F. and a third at 75° F. All cultures were examined at biweekly intervals. At each examination the wheat in the rice weevil and granary weevil cultures was replaced with fresh wheat properly conditioned, and each lot of wheat that was removed was held at the corresponding temperature for possible emergence. As adults emerged they were recorded and removed from the cultures.

Data on the survival, reproduction and development of the various species at the different temperature and grain moisture levels are recorded in tables 14, 15, and 16.

As indicated by the data of table 14, survival of all six species, at a constant temperature of 65° F., was very high at all grain moisture levels over the period of 11 weeks during which the experiment has run. To date no reproduction of any species has been observed at this temperature.

In the series held at constant temperatures of 70° F. and 75° F. the percentage of survival in most cases increased with the moisture content of the wheat.

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* Reported by R. T. Cotton and J. C. Frankenfeld, U. S. Bureau of Entomology and Plant Quarantine

Table 14: -- Survival of various stored grain insects reared in 12, 13 and 14% moisture wheat at 65° F.

Species of Insect	Percentage of survival after 1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	Number of progeny recovered
12% Wheat							
Granary weevil	100	98	96	96	96	96	0
Rice weevil	100	98	97	96	94	93	0
Confused flour beetle	100	99	99	98	98	98	0
Sawtoothed grain beetle	99	96	96	94	94	94	0
Rust red flour beetle	100	98	97	97	97	96	0
Lesser grain borer	100	100	100	100	100	99	0
13% Wheat							
Granary weevil	100	99	99	98	98	98	0
Rice weevil	100	100	100	100	100	100	0
Confused flour beetle	100	99	99	98	98	98	0
Sawtoothed grain beetle	100	98	97	96	96	96	0
Rust red flour beetle	100	100	100	100	100	100	0
Lesser grain borer	100	100	100	100	100	98	0
14% Wheat							
Granary weevil	100	100	100	100	100	100	0
Rice weevil	100	100	100	98	97	97	0
Confused flour beetle	100	99	99	98	98	98	0
Sawtoothed grain beetle	100	98	97	97	96	96	0
Rust red flour beetle	100	100	100	100	100	100	0
Lesser grain borer	100	99	98	98	98	97	0

A decided increase in the rate of reproduction was observed in the cultures of 12, 13, and 14% moisture wheat at both the 70° F. and 75° F. temperature levels as compared with previous observations on cultures in 9, 10, and 11% wheat. In 12% moisture wheat we find both the granary weevil and rice weevil reproducing readily, and a slight amount of reproduction is noted in case of the lesser grain borer. None of the three other species reproduced. In 13% wheat the above three species reproduced and in addition the sawtoothed grain beetle found conditions suitable for reproduction. However, in the case of the sawtoothed grain beetle and lesser grain borer reproduction was only slight. In 14% wheat the granary weevil, rice weevil and sawtoothed grain beetle reproduced, but not the lesser grain borer.

In the 75° F. constant temperature series the granary weevil, rice weevil, sawtoothed grain beetle, and lesser grain borer all reproduced in each of the three moisture variant wheats. The rust red flour beetle reproduced in the 13% wheat but not in either the 12 or 14% wheat. The amount of reproduction, however, was very small. The confused flour beetle did not reproduce in any of the three moisture variant wheats.

The effect of the moisture content of the wheat on reproduction of the granary and rice weevils show some interesting correlations. In the case of the granary weevil there is a decided increase in reproduction in the 13% wheat over the 12% wheat. But when the moisture content is increased to 14%, reproduction drops off, indicating that 13% wheat is apparently the optimum moisture condition for this insect. This relationship holds true for both the 70 and 75° F. series. In case of the rice weevil, the amount of reproduction increases with the increase in grain moisture. Although there is a slight difference in the percentage of survival in the different moisture variant lots, this does not appear to be great enough to account for the difference in the amount of reproduction. Reproduction figures are not yet complete for the granary and rice weevils and will be elaborated on in the next report.

The effect of temperature on the reproduction of the granary and rice weevil is also clearly shown in these tests. A larger amount of reproduction occurred in the 75° F. series for each moisture variant than in the 70° F. series.

As stated above, the lesser grain borer reproduced in 12 and 13% wheat in the 70° F. series. The amount of reproduction, however, was light and erratic. When the temperature is increased to 75° F. we find that reproduction is considerably accentuated. Furthermore, a larger amount of reproduction occurred in the 13% wheat than in the 12% wheat. But when the moisture content was increased to 14% there was no further increase. Because of the habit of the adult lesser grain borer of boring into the wheat berry, it is difficult to handle and obtain complete and accurate reproduction records. Therefore the figures cannot be considered significant, other than that reproduction occurs or does not occur.

Table 15:--Survival of various species of stored grain insects reared in 12, 13, and 14% moisture wheat at 70° F.

Species of Insect	Percentage of survival after										Number of progeny recovered after 19 weeks
	1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	13 Weeks	15 Weeks	17 Weeks	19 Weeks	
12% Wheat											
Granary weevil	100	100	97	97	95*	93	92	91	88	87	632
Rice weevil	100	100	100	52	51*	50	45	44	42	36	3307
Confused flour beetle	100	100	100	98	65	47	35	33	33	32	0
Sawtoothed grain beetle	93	87	87	87	86	84	67	55	26	18	0
Rust red flour beetle	100	99	98	91	88	81	76	64	54	43	0
Lesser grain borer	95	87	85	83	80	77	73	69	64	59*	13
13% Wheat											
Granary weevil	99	99	99	99	99*	96	96	94	94	91	2004
Rice weevil	100	100	100	54	50*	50	46	45	43	41	6696
Confused flour beetle	100	100	98	98	98	98	98	98	97	97	0
Sawtoothed grain beetle	99	93	91	91	89*	89	88	81	60	45	87
Rust red flour beetle	100	100	99	99	99	99	95	91	88	87	0
Lesser grain borer	98	97	96	94	92	92	89	83	81	78*	50
14% Wheat											
Granary weevil	100	100	100	100*	100	100	99	98	97	97	1007
Rice weevil	100	100	100	69*	66	66	64	64	63	60	7872
Confused flour beetle	100	100	100	99	99	74	1	0			0
Sawtoothed grain beetle	100	98	98	98	96*	95	93	87	84	42	86
Rust red flour beetle	100	100	100	100	97	97	96	95	93	87	0
Lesser grain borer	100	99	97	94	91	83	79	74	74	64	0

* First progeny recovered.

Table 16:--Survival of various species of stored grain insects reared in 12, 13, and 14% moisture wheat at 75°F.

Species of Insect	Percentage of survival after 1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	13 Weeks	15 Weeks	17 Weeks	19 Weeks	Number of progeny recovered after 19 weeks
12% Wheat											
Granary weevil	100	100	100	96*	93	93	93	93	91	90	1250
Rice weevil	100	100	100	80*	76	74	63	59	53	49	3594
Confused flour beetle	100	100	100	87	24	6	0				0
Sawtoothed grain beetle	95	91	91	85	78*	53	33	19	10	0	7
Rust red flour beetle	99	99	94	79	67	59	52	49	38	34	0
Lesser grain borer	94	91	86	83	76	76*					688
13% Wheat											
Granary weevil	100	100	100	97*	97	97	96	96	95	93	2421
Rice weevil	100	100	100	97*	94	91	89	82	80	66	8276
Confused flour beetle	100	100	100	42	8	0					0
Sawtoothed grain beetle	97	95	95	84*	71	57	33	19	16	5	52
Rust red flour beetle	99	97	97	96	92	86	82*	76	73	65	9
Lesser grain borer	97	91	84	80	74	74*					843
14% Wheat											
Granary weevil	100	100	100	100*	99	98	97	97	95	93	1409
Rice weevil	100	100	97	97*	97	97	95	93	85	76	10610
Confused flour beetle	100	100	100	0							0
Sawtoothed grain beetle	98	96	96*	92	88	82	67	40	31	15	110
Rust red flour beetle	100	97	97	96	95	95	89	89	87	86	0
Lesser grain borer	100	95	93	85	75	75*					829

* First progeny recovered.

Effect of the Amount of Dockage on the Ability of Tribolium confusum to Survive and Reproduce in Wheat of Various Moisture Content.*

As previously reported, earlier tests on the effect of temperature and moisture indicated that the immature stages of Tribolium confusum would not develop in clean wheat. To determine the effect of dockage in wheat a series of tests, using wheat with three different moisture variants and varying amounts of dockage, was set up. One series of tests covering a period of 18 weeks has been completed. Table 17 summarizes the results of weekly examinations, upon the percentage of survival, and the number of progeny recovered.

In the 8% moisture series the percentage of survival of flour beetles dropped rapidly in clean wheat, until after fourteen weeks no adults remained alive. With the addition of dockage, survival of adults was increased proportionally with the amount added. Seven percent survived at the end of 18 weeks in the lot with 0.5% dockage, 54% in 1% dockage, 11% in 2% dockage, 59% in 4% dockage and 85% in 8% dockage. The survival noted in the 2% dockage lot is for some unknown reason somewhat out of line, however, the data as a whole indicate that as the quantity of dockage is increased, even in wheat with 8% moisture, the percentage of survival also increases. Repeated tests will undoubtedly more definitely establish this fact. No reproduction occurred in either of the dockage variant lots at this moisture level.

In the 12 and 14% moisture series very little difference is noted in the percentage of survival of adult T. confusum in the different dockage variant lots. The fact that a high survival occurred in the clean wheat is unquestionably due to the high moisture content of the wheat. Wheat with a fairly high moisture content is softer and therefore more suitable for the feeding of T. confusum than the drier, harder wheat. Furthermore, the higher relative humidity of the air in the breeding chamber prevents dehydration which undoubtedly is a factor in survival.

While no apparent effect is noted in the percentage of survival, there is a tendency for increased reproduction with the increase in the percentage of dockage added. This relationship is best shown by the data of the 12% moisture series, table 17. It will be noted that the number of progeny, recovered as pupae, at the end of 18 weeks varied from 26 in the clean wheat, to 397 in the wheat with 8% dockage.

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* Reported by R. T. Cotton and J. C. Frankenfeld.

The lower rate of reproduction observed in the 14% moisture series is of considerable interest. The relative humidity required to maintain wheat at a moisture content of 14% is about 62%. It hardly seems likely, that fungus which is extremely effective in destroying the eggs, could be active enough at this relative humidity to be the causitive agent, however, that this is a possibility is indicated by the scarcity of larvae and pupae in the lots with 4 and 8% dockage. No fungus growth was discernible in any of the lots from casual observations, which is not conclusive evidence that fungi are not present. Further tests are planned to definitely establish this relationship.

That the immature stages of the confused flour beetle are unable to develop in clean grain is indicated, although not definitely established. It will be noted that, besides the reduced number of pupae obtained in the clean wheat, the date on which pupae were first recovered was a week or so later than in the lots containing dockage. Showing that the immature stages apparently cannot develop until sufficient flour has been milled by the adult beetles. This fact has been observed in other tests where only clean wheat was used. In these tests the insect milled flour is not removed, because of the difficulty encountered in separating the eggs from this milled flour. It is believed therefore that the adult beetles will oviposit in clean wheat, but until sufficient dockage accumulates the resulting larvae are unable to obtain sufficient food to maintain life and complete development.

Table 17: -- Survival of Tribolium confusum in 8, 12, and 14% moisture wheat with varying percentages of dockage at 80° F.

Rearing medium	Percentage of survival after																Number of progeny
	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks	7 Weeks	8 Weeks	9 Weeks	10 Weeks	11 Weeks	12 Weeks	13 Weeks	14 Weeks	15 Weeks	16 Weeks	17 Weeks	18 Weeks	
8% Moisture																			
Clean whole wheat	100	97	87	72	52	51	51	49	28	14	9	6	1	0	0				0
Same plus 0.5% dockage	100	100	100	99	99	99	98	98	90	85	70	48	38	20	17	13	10	7	0
" " 1.0% "	100	100	98	90	86	85	85	85	85	84	82	82	80	77	74	71	63	54	0
" " 2.0% "	100	99	96	89	81	78	74	74	70	67	64	62	53	45	34	27	15	11	0
" " 4.0% "	100	100	99	98	97	93	91	88	83	81	80	80	76	71	68	64	62	59	0
" " 8.0% "	100	100	100	100	98	97	97	96	96	96	96	95	94	93	93	92	89	85	0
12% Moisture																			
Clean whole wheat	100	99	99	99	99	99*	98	98	97	97	96	96	96	96	96	96	96	92	36
Same plus 0.5% dockage	100	100	100	100	100*	100	100	100	100	100	98	98	98	98	98	98	98	98	152
" " 1.0% "	100	100	100	100	100*	100	100	100	100	100	100	100	100	100	100	100	100	100	242
" " 2.0% "	100	100	100	100	100*	100	99	98	98	98	98	98	98	98	98	98	98	97	298
" " 4.0% "	100	100	100	100	100*	100	100	100	100	100	100	100	100	100	100	99	99	99	211
" " 8.0% "	100	100	100	100*	100	100	100	100	100	100	100	100	100	100	100	100	99	99	397
14% Moisture																			
Clean whole wheat	100	99	99	99	99	99	99*	99	99	99	99	99	99	99	99	99	98	98	46
Same plus 0.5% dockage	100	100	100*	100	99	99	99	99	98	98	98	98	98	98	98	98	98	98	60
" " 1.0% "	100	100	100*	100	100	100	100	99	99	99	98	98	98	98	98	98	97	97	24
" " 2.0% "	100	100	100	100*	99	99	99	99	99	99	99	99	99	99	99	99	99	98	120
" " 4.0% "	100	100	100	100	100	100	100*	100	100	100	100	100	100	100	100	100	100	99	8
" " 8.0% "	100	99	99	99	99*	99	99	99	99	99	99	99	99	99	99	99	99	99	7

* Period first pupae were recovered.